IN THE SPECIFICATION:

Please replace paragraph **[0001]** with the following:

[0001] Field of the Invention: The present invention relates to the field of extendible truss structures~~, and~~ and, more ~~particularly~~ particularly, to lightweight deployable truss structures used in space applications.

Please replace paragraph **[0004]** with the following:

[0004] In general, a cylindrical shell, or tube, is a simple and mass efficient structure. However, STEMs have strength limitations since the deployed metal strip does not form a closed section. Multiple overlapped STEMs, such as ~~the~~ those shown in various figures of U.S. Patent 3,434,674 and methods of interlocking the overlapped section(s) (see, e.g., figure 8 of U.S. Patent 3,144,104) have been pursued to increase strength.

Please replace paragraph **[0009]** with the following:

[0009] One bay of a typical collapsible four-sided lattice structure is shown in FIG. 1 of U.S. Patent ~~5,106,418~~5,016,418, issuing to Rhodes et al, the disclosure of which is hereby incorporated by reference. Each bay, or structural unit, is constructed of structural members connected with hinged and fixed connections at connection nodes in each corner of the bay. Diagonal members along each face of the bay provide structural rigidity and are equipped with mid-length, self-locking hinges to allow the structure to collapse. Many other clever schemes for the articulated folding of repeating bay booms, or truss structures, have been arranged.

Please replace paragraph **[0015]** with the following:

[0015] Articulated and coilable lattice truss structures have been successful to date in providing low mass solutions to a wide array of lightly-loaded truss structures (relative to terrestrial structures) for use in space applications. But many potential space applications, including, for example, even more lightly loaded or "gossamer" applications and imaging mission applications requiring lightweight and stable structures, call for extendible structures having compaction, stability, and/or mass efficiency requirements that are outside the

capabilities of existing structures or are not easily met by such structures. Accordingly, the ever increasingly challenging requirements for compaction, stability, and mass efficiency call ~~for a new~~for new generation extendible structure solutions.

Please replace paragraph **[0020]** with the following:

[0020] Inflatables, folded, and flattened lattice structures do not have precise kinematics and suffer from reduced stiffness and strength during deployment. Articulated lattice structures have precise kinematics that can be controlled by separate actuators and rate limiting devices. The reliability inherent in the heritage methods of deploying articulated lattice structures is also a key performance parameter. Reliability is another fundamental criteria in the creation of a desirable deployable ~~structures~~ structure for use in space applications, alongside mass efficiency, compact stowage performance, and stability.

Please replace paragraph **[0021]** with the following:

[0021] A need, therefore, exists for deployable truss structures that improve on one or more of the above noted deficiencies of currently known deployable truss structures, yet maintain the reliable deployment characteristics of articulated and coilable lattice structures. Preferably, such truss structures would also improve on at least one of the attributes of mass efficiency, stowage volume, and thermal stability, and preferably all three. A need also exists for such structures that can make practical use of high-performance graphite fiber elements. A need further exists for column members that will enable improved deployable truss structures to be built.

Please replace paragraph **[0025]** with the following:

[0025] The phrase ~~column members~~ "column members" is used herein to refer to structural members of the truss designed to resist both compressive and tensile axial forces.

Please replace paragraph **[0042]** with the following:

[0042] Figs. 8A-8D are various views of a deployable articulating boom truss structure according to the present invention. Fig. 8A is a perspective view of a deployable truss structure according to the present invention in its collapsed state attached to a satellite. Fig. 8B is a perspective view of the entire structure during deployment of the truss structure. Fig. 8C is a partial side view of the truss structure during deployment. ~~Figure 8D~~Fig. 8D is a partial side view of the structure in a deployed position.

Please replace paragraph **[0054]** with the following:

[0054] Fig. 1C illustrates two bays 61 of a deployable boom truss 60 according to one embodiment of the present invention. As discussed more fully below, deployable boom truss 60 may be an articulating truss structure or a coilable truss structure. Deployable boom truss 60 comprises a plurality of column members 64 connected at their ends at node joints 65. Two crossing diagonal cable stays 67 are provided on each face of bays 61 to add additional structural rigidity to deployable boom truss 60. In the present embodiment, the column members 64 forming the longeron elements of bays 61 comprise column assemblies 66. Each column assembly 66 comprises three strut members 68 that are connected to each other at a first end 70 of the column assembly and at a second end 72 of the column assembly. As illustrated, strut members 68 are preferably symmetrically arranged about the centerline of their respective column assembly 66. Each column assembly 66 of the present embodiment also includes a spacer 74 connecting the strut members of the column assembly at a location between the first and second ends 70, 72 of the column assembly, and preferably at the mid-point between the two ends. Spacers 74 brace the strut members 68 of each column assembly so that they are mutually stabilized and symmetrically spaced from the centerline of their respective column assembly. To ~~fitting~~ fit size, and mass, at the node joints 65, however, the strut members 68 are preferably tapered toward the first and second ends 70, 72 of the column assemblies 66.

Please replace paragraph **[0055]** with the following:

[0055] By locating spacers 74 in the middle of column assemblies 66, as illustrated, the effective buckling length of each strut member is effectively cut in half while the effective diameter, and hence moment of inertia of the column assembly 66 is increased. Indeed, by spacing strut members 68 about the centerline of column assemblies 66 a distance equal to the radius of columns 44 shown in Fig. 1B, the section inertia of column assemblies 66 will be comparable to that of ~~column members~~ columns 44. As a result, deployable boom truss 60 of the present invention can provide comparable bending stiffness to that of boom truss 42, yet with substantially less mass.

Please replace paragraph **[0058]** with the following:

[0058] Figs. 2A-D are used to further qualitatively illustrate the structural efficiency of using column assemblies according to the present invention as column members in a deployable truss. Consider a thin-walled composite tube 80, as shown in Fig. 2A. Assume that this thin-walled composite tube has the necessary cross sectional area, section inertia, and minimum wall thickness to satisfy the stiffness and strength requirements of a given application when used as a column member in a deployable truss. Fig. 2B shows a solid rod 82 with the same cross sectional area (not shown to scale in figures) of the composite tube 80. The solid rod 82 would have the same axial stiffness and strength in tension as tube 80 since they have the same cross-sectional area, but would buckle in compression at a much lower load since the section inertia of the solid rod 82 is much lower than the section inertia of the tube 80. The cross sectional area of tube 80 could similarly be separated, or stranded, into a number of smaller diameter rods or tubes. For example, Fig. 2C shows the cross sectional area of tube 80 being divided equally into three solid rods 84. A column formed from the three rods 84 would collectively duplicate the axial stiffness and strength in tension of the original tube 80 shown in Fig. 2A but not its strength in compression, because the section inertia of the three solid rods 84 as arranged in Fig. 2C is much lower than the section inertia of tube 80. Further, the section inertia of the rods 84, as arranged in Fig. 2C, may also be less than the section inertia of the single solid rod 82. But, if, as shown in Fig. 2D,

rods 84 are mutually stabilized and equally spaced from the centroid by a spacer so as to lie on a circle 86 equal to the diameter of the original tube 80 as shown in Fig. ~~1D~~ 2D, the section inertia of the configuration will approximate the section inertia of the original ~~tube 20~~ tube 80. Thus, dividing the cross sectional area of a tube into rods, and spacing those rods equally on a circle equal to the diameter of the original tube will approximate the cross sectional area and section inertia of the original tube. However, by spacing those rods evenly on a circle of even greater diameter than the diameter of the original tube would make the section inertia of the system of rods greater than the section inertia of the original tube. Similarly, a series of spaced tubes could be used instead of a series of rods to replace the original single tube.

Please replace paragraph **[0060]** with the following:

[0060] Fig. 3 illustrates a deployable truss 90 according to another embodiment of the invention in a partially deployed state. Deployable truss 90 comprises a plurality of contiguously attached deployable bays 92. In the present embodiment, bays 92 are in the form of parallelepipeds. Each of the column members of the truss comprise column assemblies 66 according to the present invention. Further, each of the column assemblies 66 ~~are connected at their~~ is connected at its ends at node joints 94. Joints 94 provide for articulation of the structure at the node. A variety of such node joints suitable for the present application ~~are well known~~is well known in the art. Diagonal cable stays are also included in deployable truss ~~structure~~ 90, but have been omitted for clarity.

Please replace paragraph **[0063]** with the following:

[0063] Fig. 4 schematically illustrates various embodiments of column assemblies according to the present invention. Column assemblies 120, 130, 140, and 150 illustrate column assemblies comprising curved continuous strut members 68 with increasing levels of bracing by spacers 74. Column assemblies 160, 170, 180, and 190 illustrate column assemblies having increasing bracing and employing straight strut elements 192 between bracing points to form strut members 68. Segmenting strut members 68 into straight strut elements 192 between intermediate bracing points provided by spacers 74, as illustrated in column

assemblies 160, 170, 180, and 190, will maximize strength and stiffness of the strut members 68. This is because smaller eccentricity of the strut members 68 from an imaginary line connecting spacing positions should increase buckling strength and stiffness of the strut members 68. On the other hand, forming strut members 68 from one section of, for example, a continuous fiber reinforced composite rod or tube that is curved during assembly allows more economical construction of the column assemblies from longer lengths of material. As further illustrated in Fig. 4, the strut members 68 of a column assembly may be braced at an arbitrary number of intermediate locations. However, there is a trade off between increased bracing and increased mass. As a result, from a mass optimization ~~stand point~~standpoint there may be a diminishing value of return as the number of bracing points increase. It should also be noted that in certain implementations of the present invention, which are discussed more fully below, it may be desirable not to provide any bracing.

Please replace paragraph **[0064]** with the following:

[0064] As noted above, eccentricity of the strut members from an imaginary line connecting fixed spacing points of the strut members affects their buckling resistance. Generally, a smaller level of eccentricity results in increased buckling strength and stiffness. As best seen from Fig. 5, if strut members are formed from continuous lengths of material, the angle held when the strut members are bonded into a node fitting can be optimized to minimize eccentricity. Fig. 5 schematically illustrates two column assemblies 200 and 220 according to the present invention. Two strut members 202, 206 of column assembly 200 are shown, and two strut members 222, 226 of column assembly 220 are shown. Strut members 202, 206, 222, and 226 are formed from continuous curved members. In the lower column assembly 200, strut members 202, 206 are permitted to naturally curve from fixed bracing points 214, 216 to the end of the column assembly with a pin-ended connection. As a result, the angle between the strut members 202, 206 and centerline 210, which coincides with the line of action of the buckling load on the column assembly, is fairly large. This in turn results in strut members 202, 206 having some level of eccentricity represented as A in Fig. 5. Moreover, all of the eccentricity of strut members 202, 206 falls outside of imaginary line 209. In the upper column assembly 220, the angle formed between the strut members 222 and 226 at the

connection and the centerline 230, which also coincides with the line of action of the buckling lode on the column assembly, has been optimized to reduce eccentricity of strut members 222, 226 from imaginary line 229 connecting bracing points 234, 236 and the end of the column assembly. The angle is reduced by connecting ~~struts~~ strut members 222 and 226 in a fixed end condition and such that the tangent of ~~struts~~ strut members 222 and 226 at the fixed connection approaches or even aligns with centerline 230. As seen from Fig. 5, by reducing the angle that strut members 222 and 226 approach the end of column assembly 220, the maximum amount of eccentricity of the strut members is reduced by 1/2 to A/2. Furthermore, the eccentricity of strut members 222, 226 is now more balanced on both sides of imaginary line 229. The angle held by strut members 222, and 226 may be set based on the angle at which the strut members are bonded into the node fittings (not shown). Figure 5 illustrates merely the practical limiting cases on the variability in eccentricity for a column assembly with a single spacer. Proper angle constraints for structural optimization of columns with other numbers of spacers would be evident to those skilled in the art from the above discussion.

Please replace paragraph **[0065]** with the following:

[0065] While the column assemblies according to the present invention are not required to be tapered at their ends in all implementations of the invention, failing to taper a latticed column assembly according to the present invention, such as column assembly 66, can increase the size of the node fittings at the connections because a node fitting that has to join strut ~~members 74~~members 68 that are spaced apart, must by definition be larger. On the other hand, smaller node fittings, having less mass, can be used if the strut members at each end of the column assembly are tapered toward the centerline of the column assembly as illustrated in Fig. 5. Further, by tapering the strut members to minimize eccentricity as illustrated by column assembly 220 of Fig. 5, even smaller node fittings can be used, thereby further improving mass efficiency.

Please replace paragraph **[0068]** with the following:

[0068] The nesting height of a large number of such spacers is the total height of the spacers stacked on top of each other divided by the number of spacers. For example, the stack height of the spacers 270, 280 in Fig. 6A is shown as ~~distance 284~~ distance 285 and is approximately the distance between strut member 264 of spacer 280 and strut member 250 of spacer 270. A smaller nesting height generally results in an increase in storage compaction. As shown in Fig. 6A, leg 276 of spacer 270 contacts spacer 280 at central strut member 266 when spacers 270 and 280 are nested. Figs. 6A-D collectively demonstrate that spacer designs allowing a central strut member limits the minimum achievable nesting height when stowing multiple spacers of an identical design. Because high compaction is an important goal of all deployable space structures, foregoing a central strand would be advantageous when employing fixed spacers in the column assemblies according to the present invention to improve nesting.

Please replace paragraph **[0069]** with the following:

[0069] Fig. 7 illustrates the nesting improvement achieved using a V-shaped fixed spacer that does not include a central strand. ~~Fig. 6~~Fig. 7 shows two V-shaped spacers 300, 320 having legs 308, 310 and 328, 330, respectfully. Spacer 300 spaces strut members 302, 304, and 306, while spacer 320 spaces strut members 322, 324, and 326. The stack height of two spacers 300, 320 of Fig. 7 is distance 334, which is much smaller than the stack height ~~284~~ or distance 285 of the two spacers 270, 280 shown in Fig. 6A. Indeed, the V-shaped fixed spacer design illustrated in Fig. 7 would permit a large number of column assemblies employing such spacers to be stacked in approximately one-fourth the height of tubular columns having a diameter equal to the effective diameter of the column assembly.

Please replace paragraph **[0074]** with the following:

[0074] When fully ~~deployed~~ deployed, the truss structure 360 carries panels 366 on one side and panels 368 on the opposite side. The deployed volume of the multipanel structure is orders of magnitude greater than its stowed volume. For example, a deployable truss

structure 360 employing the second order augmentation of the present invention can be designed to stow within the payload area of a Delta IV-Heavy rocket yet when fully expanded measure over 500 m long. By comparison, using conventional deployable truss technologies, a deployable truss having a deployed length of only 300 m could fit within the same payload area.

Please replace paragraph **[0075]** with the following:

[0075] The column assemblies, and hence the truss structures, according to the present invention can be stowed more compactly if the strut members are spaced with a deployable spacer instead of a fixed spacer. Because it has been analytically found that the stiffness of the column assemblies is relatively insensitive to spreader stiffness and that the energy required to spread the strut members is relatively small, a wide variety of deployable spacer designs are possible. Various deployable spacers for separating four strut members and their corresponding configuration for strut member deployment are illustrated in Figs. 9A-9F. The strut members are separated by a strained hoop in Fig. 9A, a hinged cross brace in Fig. 9B, a sprung frame in Fig. 9C, carpenter tape strips in Fig. 9D, an inflatable sphere in ~~Fig. 8E~~Fig. 9E, and inflatable bellows in Fig. 9F. The methods used to spread the strut members can thus, for example, include the use of strain energy, elastic memory composites, and inflation gas. A chart listing some of the pros and cons of the different methods to spread the rods is included in Table 1, below.

Please replace paragraph **[0079]** with the following:

[0079] Figs. 11A and 11B show the deployment of strut members 590, 592, 594, and 596, using a deployable spacer formed from carpenter tape strips 580, 582, 584, and 586. ~~Fig. 10A~~Fig. 11A shows the strands in a collapsed position, while ~~Fig. 10B~~Fig. 11B shows the deployed position with the carpenter tapes expanded. In the collapsed state, the carpenter tape strips are wound on ~~spools 596~~spools 597.

Please replace paragraph **[0081]** with the following:

[0081] The hinged/sliding spacer 600 provides a very compact stowage volume, with springs 620, 622, 624 using the same volume around the strut members <u>or rods</u> 602, 604, 606 as the fixed and sliding fittings. This dimension is key to allowing the column assembly to stow as compactly as allowed by the strut members themselves.

Please replace paragraph **[0083]** with the following:

[0083] Referring to Fig. 12A, hinged/sliding spacer 600 is shown in a stowed position with collapsed rods 602, 604, and 606. Fig. 12B shows hinged/sliding spacer 600 in mid-deployment. Hinged/sliding spacer 600 comprises hinged legs 610, 612, and 614 and springs 620, 622, and 624. The first leg 610 of hinged sliding spacer 600 connects rod 602 to rod 604, the second leg 612 connects rod 606 to ~~602~~<u>rod 602</u>, and the third leg 614 connects rod 604 to ~~606~~ <u>rod 606</u>. Spring 620 acts on the first leg 610, spring 624 acts on the second leg 612, and spring 622 acts on the third leg 614. Each leg of the ~~hinged/slider spacer~~<u>hinged/sliding spacer 600</u> comprises a lower and upper collar 640, 644 a pivot ~~aim 642~~ <u>arm 642</u>, and two pivot pins 646, 648. The upper collar 644 of each leg of the hinged/slider spacer is fixed to its respective ~~strut member~~<u>rod</u>. Lower collar 640 of leg 614 slides over rod 604, upper collar 644 which is fixed to rod 606 through pin connection 650, and pivot arm 642 is connected to the upper collar 644 through pivot pin 648 and connected to the lower collar 640 through pivot pin 646. During deployment, springs 620, 622, and 624 expand forcing the lower collars on the hinged/slider spacer higher up their respective rods. Each lower collar has a fixed tab 632 that mates with a recess 630 on each of the upper collars. Fig. 12B shows fixed tab 632 on lower collar 640 of slider leg 614. Fixed tab 632 mates with recess 630 on the upper collar of leg 610.

Please replace paragraph **[0085]** with the following:

[0085] As noted above, the column assemblies according to the present invention can also be incorporated into coilable trusses to provide them with the benefits of second order augmentation. A preferred configuration of a coilable truss 800 according to the present

invention is depicted in Fig. 14. Coilable truss 800 comprises a plurality of column members, including column assemblies 802 and battens 804, connected at their ends at truss nodes 806. Column assemblies 802 comprise a plurality of strut members 810 connected to each other at a first end 812 of the column assemblies and at a second end 814 of the column assemblies. In the present embodiment, each column assembly 802 further comprises a deployable spacer 816 connecting the strut members 810 of the column assembly at a location between the first and second ends of the column assembly. However, in other embodiments of a coilable truss according to the present invention, no spacer is used. ~~Preferably~~ Preferably, a deployable spacer connects the strut members near the midpoint between the first and second ends. If more than one deployable spacer 816 is included in each column assembly, they are preferably spaced approximately equally between the first and second ends of the column assembly.

Please replace paragraph **[0087]** with the following:

[0087] In the present embodiment, column assemblies 802 form three longerons 818 that are arranged parallel to one another and that extend the length of the truss. Further, strut members 810 are continuous members that extend the length of longerons 818. As a result, longerons 818 are jointless and strut members 810 pass between truss nodes 806 between contiguous column assemblies as illustrated in Fig. 15. As also illustrated in Fig. 15, the column assemblies of the present embodiment each include four strut members 810, but in alternative ~~embodiments 3~~embodiments, three or more strut members may be employed. Longerons 818 are connected to a pair of end plates (not shown) in manner customary to conventional coilable trusses. Battens 804 brace the three longerons at regular intervals corresponding to the ends of the column assemblies 806 to define a plurality of bays 819 along the length of the truss 800. In alternative embodiments of the invention, battens 804 may be replaced with column assemblies 802 according to the present invention or radial spacers, such as in U.S. Patent No. 4,918,884. Diagonal cable stays 820 are stretched between opposing truss nodes 806 on each face of the bays 819 in a conventional manner.

Please replace paragraph **[0088]** with the following:

[0088] Coilable truss 800 is collapsed and deployed using conventional methods. To collapse truss ~~structure~~ 800, the longerons are elastically buckled between battens 804 so as to coil the longerons between the endplates (not shown).

Please replace paragraph **[0090]** with the following:

[0090] The use of column assemblies having deployable spacers in a coilable lattice structure allows for the possibility of creating a deployable coilable lattice structure with considerably greater cross section than conventional coilable trusses would permit. Such a lattice structure can be easily coiled for storage with acceptable strains since the strain is directly related to the diameter of the strut members. In addition, because the strut members 810 of the column assemblies are of a much smaller diameter than the diameter of the tubes or rods in conventional coilable trusses, the stowed strain energy can be much lower in the coilable trusses of the present invention compared to the stowed strain energy in a ~~convention~~ conventional coilable truss structure. Alternatively, because stowed strain energy can be significantly reduced by employing the secondary augmentation technique of the present invention, the size of the deployment equipment can be reduced, thereby reducing the parasitic mass associated with the truss structure 800.

Please replace paragraph **[0091]** with the following:

[0091] Fig. 13 illustrates a range of stranding options for strut members of column assemblies according to the present invention. Near the center of Fig. 13 is shown a cross section of a column, depicted as a circular rod 700, that is to be replaced with a column assembly according to the present invention. Circular rod 700 could also be a tube. Circular rod 700 could be a member of a lattice truss, such as a batten, diagonal or longeron. Referring to Fig. 12, moving vertically up from rod 700, there is a column 705 formed from three circular rods, with the cross sectional area of each of the three rods that comprise column 705 being one third the cross sectional area of circular rod 700. Thus, the sum of the cross ~~section~~ sectional area of the three rods 705 is the same as the cross sectional area of circular rod 700.

Replacing rod 700 with column 705 is one of the simplest embodiments of a column assembly according to the present invention. Such a replacement is referred to as stranding. In a slight variation of this embodiment, the three rods of column 705 could be twisted about their collective centerline to limit brooming as discussed above if used in a coilable truss application.

Please replace paragraph **[0099]** with the following:

[0099] ~~Often~~ Often, coilable lattice designs are limited in their structural stiffness and strength for a given overall structure diameter by the strain that the longeron material can withstand. The strain is calculated by the longeron strand diameter over the structure diameter. Heritage glass fiber coilables are typically designed to 1.5% strain. Using graphite fiber composites may restrict the usable longeron diameter by a factor of three or more. By stranding the longeron, a greater total area of material can be utilized. This allows the designer to take advantage of the stiffness-to-weight performance of graphite fiber composites without the achievable area (stiffness) being limited by stowed strain.

Please replace paragraph **[00101]** with the following:

[00101] However, multiple methods of fusing the strands or strut members of a non-expanded column assembly together (after deployment) to obtain more substantial resistance to strand separation (and hence individual buckling) are possible. For example, a rigidizable resin, such as a thermoplastic resin or UV curable resin could be employed in such applications. ~~Preferably~~ Preferably, a thermoplastic resin is employed so that deployments of the structure could be repeated on the ground to prove reliability prior to use in orbit.

Please replace paragraph **[00106]** with the following:

[00106] While variants of the common lattice structure are preferred and well utilized, according to the present invention reformation of the required structure area in the first-order lattice into stranded column assemblies will allow further advantages. One example is tighter stowed packaging: Open lattice column assemblies can be nested to increase

compaction by at least a factor of 4. The basic structural advantages of a lattice over a thin-walled shell are realized again with the secondary latticing. ~~Thus~~ Thus, the realization of higher mass efficiency and compaction benefits are compounded.